UNCD Related Carbon Nanocomposites

X. Xiao, O. Auciello, J.W.Elam, J. Wang, J. Birrell , J.E. Gerbi, D. M. Gruen, J. A. Carlisle*
Material Science Division, Argonne National Laboratory, Argonne, IL, 60439

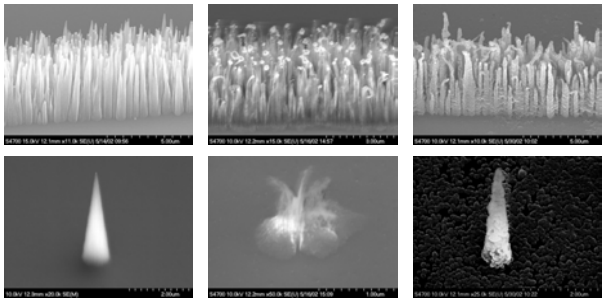
Motivation/Major accomplishments

Carbon-based materials exhibit excellent physical, chemical, mechanical, tribological, and transport properties that are dictated by the many different bonding configurations available to carbon. Three types of carbon-based materials, ultrananocrystalline diamond (UNCD) films, carbon nanotubes (CNTs), and carbon nanofibers (CNFs), each with their specific bonding state and unique properties, are of particular research interest. Recent advances in micro and nanofabrication techniques have made possible the development of microscale and perhaps even nanoscale devices that capitalize on the many intrinsic strengths of these carbon-based materials. The focus of our study has been to achieve conformal coating of UNCD deposition, to study the field emission properties of UNCD/CNFs composites, and to develop new fabrication techniques for controlled growth of CNTs and UNCD/CNTs composites. The configuration and alignment of of CNTs could be controlled through adjusting plasma chemistry and catalysts. The UNCD/CNTs nanocomposite has been prepared in one deposition step by appropriately addressing the seeds for UNCD and catalyst for CNTs.

Carbon based nanostructured materials are of scientific and practical significances. The good conformality of UNCD coatings, together with their capability to be deposited at low temperatures, expands the application of UNCD in the MEMS and electronic field, where the metallization process sets limit on the temperature that can be used for all subsequent processes. The UNCD/CNFs composite can be used as field emitters for flat panel displays with its improved field emission properties; it can also be used as microprobes such as AFM tips and the high mechanical integrity of UNCD ensures robust and reliable device performance. The capability to control the configurations and alignments of CNTs, and the success to grow CNTs and UNCD simultaneously, provided a novel approach to fabricate "self-assembly" nanoelectronic devices based on CNTs.

RESULTS

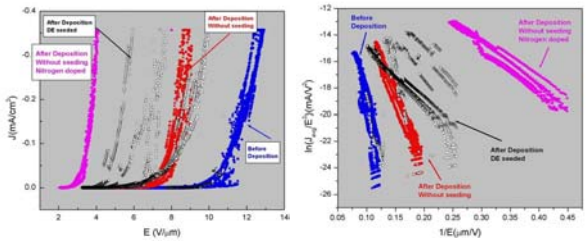
UNCD/CNFs



Before deposition | Without seeding After deposition | With seeding After deposition

- UNCD can't be deposited on CNFs directly
- CNFs can't stand the Plasma etching, similar phenomena have been found for CNTs and a-D
- Diamond seeding layer protected CNFs and also served as nucleation layer for UNCD deposition

Field Emission Properties of UNCD/CNFs

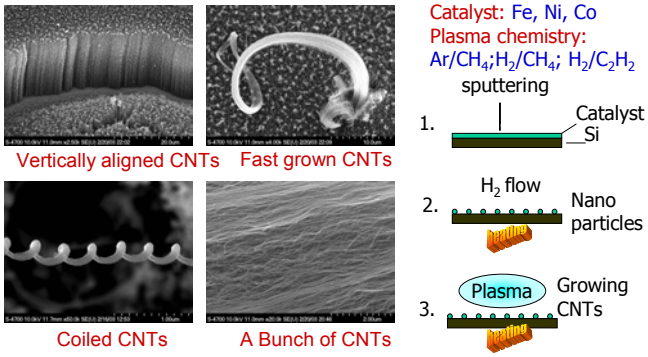


I-V characteristics | F-N plot

Fowler-Nordheim equation: $J = A\beta E^2 / \Phi \exp(B\Phi^{3/2} / \beta E)$

The slope of $\phi^{3/2}/\beta$, represents the combined effect of effective work function and enhancement of local electric field;
$\because \phi^{3/2}/\beta \downarrow$ & $\beta \downarrow \quad \therefore \ \phi \downarrow\downarrow$

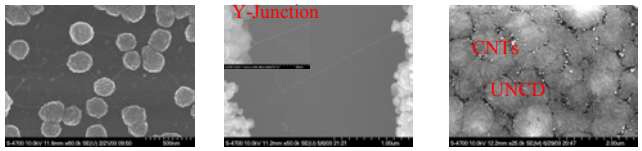
CNTs and UNCD/CNTs



Vertically aligned CNTs | Fast grown CNTs

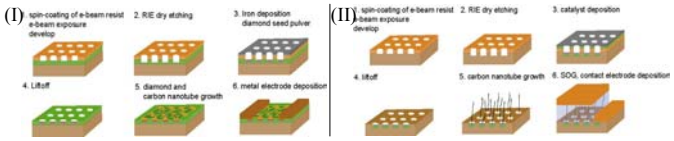
Coiled CNTs | A Bunch of CNTs

- CNTs and UNCD can be deposited simultaneously. The key is how to address the catalyst for growing CNTs and the seeds for growing UNCD



UNCD/CNTs | CNTs connected pattern | UNCD/CNTs

Each super UNCD particle (randomly distributed) is connected by CNTs, "Self-assembly nanoelectronic circuit" of UNCD and CNTs could be achieved



Schematic of process sequence for fabricating nanostructures using CNTs which are connected laterally via UNCD (I) and and aligned vertically for transportation measurement (II)

FUTURE WORK

- To fabricate the prototype of AFM tips based on the UNCD/CNFs hybrid structure
- To design nanoelectroic devices and further characterize the transport properties of different types of CNTs

BES - DOE

This work was supported by the U.S. Department of Energy, Basic Energy Sciences, under contract W-31-109-ENG-38

MSD - ANL